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AGROCLIMATIC ZONING OF SUGAR BEETS IN WESTERN SIBERIA

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One of the primary tasks in sugar-beet production is to study the natural resources for the purpose of introducing sugar-beet growing in new areas and to increase the yield and sugar content of the beets. This especially concerns Siberia where sugar beet production is just beginning in many areas, and in other areas sugar beets have been cultivated for a relatively long time (Altai), but not all sugar-beet growers have secured rich and stable yields. Due to these facts, a consideration of climatic conditions in organizing sugar-beet production in Siberia presents one of the most important links in economic zoning of this crop as a whole.

Principally, agroclimatic zoning can be reduced to establishing the presence of climatic conditions determining a certain level of yield, then to mapping these conditions and to outlining on this basis agroclimatic areas for sugar-beet production. One of the most difficult problems involved is the elaboration of quantitative agroclimatic indexes for sugar beet.

Investigations in this field [1, 2, 4, 6, 7, 8, 9, 10, 11, and 12] indicate the necessity of further detailed elaboration of quantitative indexes describing the interrelations between the plant organism of the sugar beet and the climate. Some sources present established indexes of a highly tentative nature [2]. In other sources, the dependence of the yield and sugar content of beets on climatic conditions comes to the elucidation of separate data on the process of root growing and sugar accumulation for a particular time and locality [1, 6, 7, 10, and others]. The usage of quantitative indexes established in the course of some agrometeorological investigations [4 and 9] is difficult due to the absence of necessary agrometeorological data for new areas of sugar-beet growing.

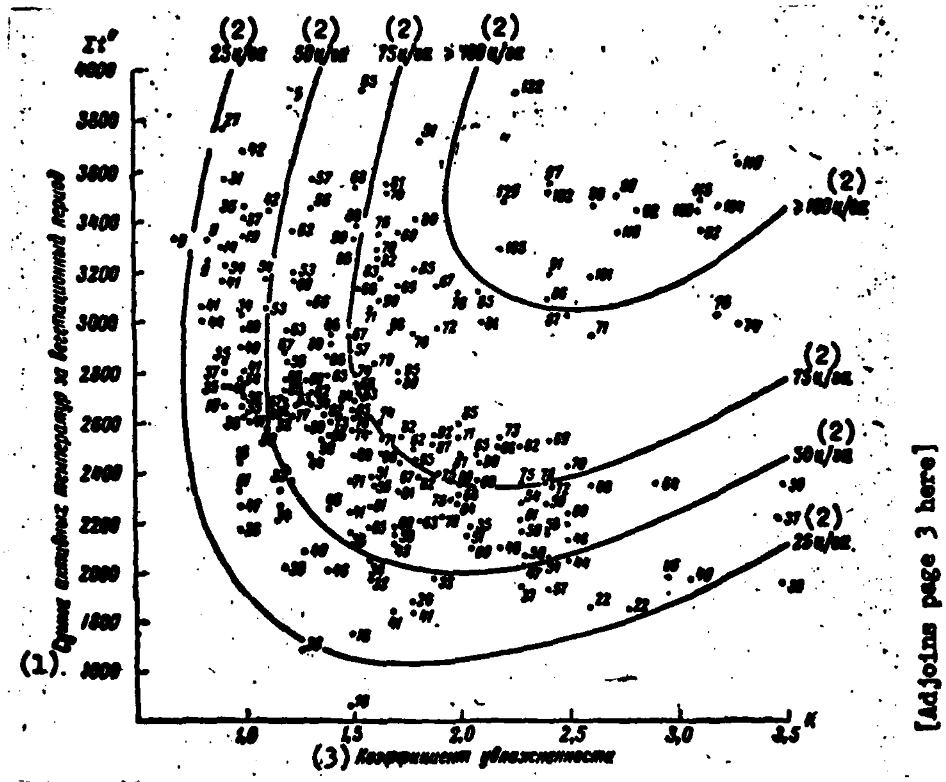


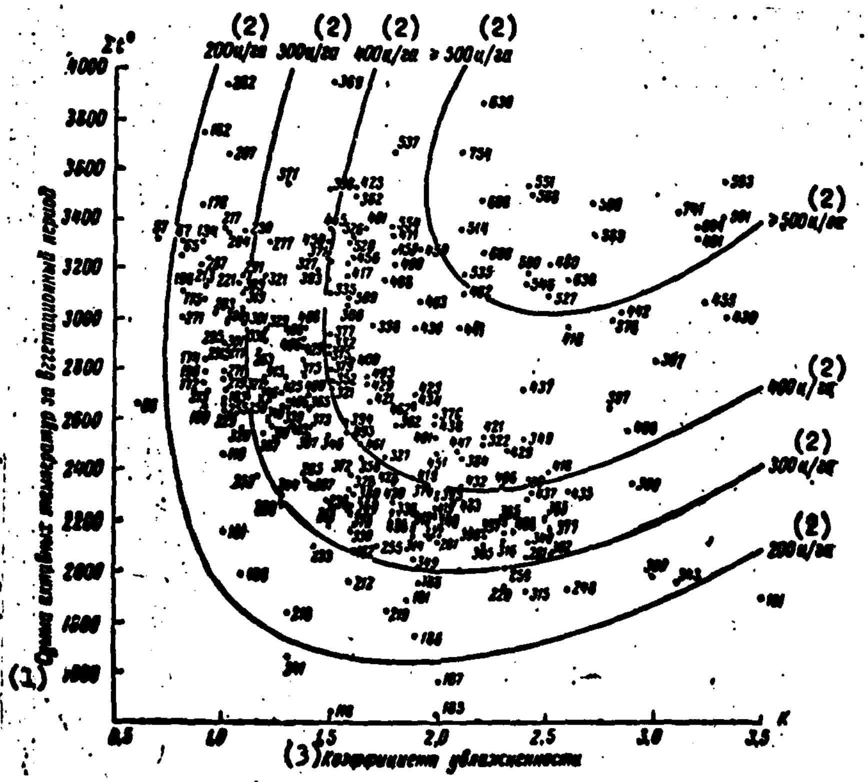
Figure 1. Dependence of root yield (left) [graph page 2] and sugar production (right) [graph page 3] on the sum of temperatures and coefficient of moistening.

KEY:

1 - The sum of active temperatures during the vegetative period
2 - Centner/hectare
3 - Coefficient of moistening

Translator's note: Apparently there is an error in the original. Data on the root yield are evidently on page 3, data on the sugar production - on page 2. Compare Table 1.

[Adjoins page 2 here]



We elaborated quantitative indexes in the first approximation by establishing a relationship between climatic factors and the sugar-beet yield, the sugar content of the beets, and the sugar yield.

Taking into account the simplicity of determining the sum of active temperatures and the availability of data for computations, we tried to use them for both characterizing the heat requirements of the sugar beet and evaluating the thermic resources of the territory. As the principal index describing moisture conditions, the coefficient of moistening was taken:

$$K = \frac{0,6\,\Sigma_{r_1} + \Sigma_{r_2}}{\Sigma t^\circ : 10},$$

where 0.6 is effectiveness;

Σ_{r_1} is the amount of precipitation during the nonvegetative period (from the last year's harvesting till the next year's sowing);

Σ_{r_2} is the amount of precipitation during the vegetative period;

$\Sigma t^\circ : 10$ is the sum of temperatures during the vegetative period divided by 10 (conditionally it presents a possible value of evaporation).

The coefficient of moistening was calculated according to Selvaninov's method but with taking into account the winter precipitation.

Relationships established between the indexes describing heat and moisture conditions and the sugar-beet productivity (Figure 1) were used as a basis for zoning. Graphs were constructed on the basis of data on yearly sugar-beet yields and on sugar production taken from reports of sixty crop-testing stations attached to the State Commission on Strain Testing of Crops, for the period of 1955-1961. In the process of data analysis, the years were excluded when the snow retention was applied or other nonclimatic factors had an influence on yields. A possibility of the influence of differences in soil on the beet yield was excluded by using data secured only from crop-testing stations located within the chernozem zone.

In addition to establishing basic relationships between climatic factors and sugar-beet yielding capacity and productivity, we also analyzed the influence of climate on the sugar content of the beets. We found that sufficient moisture and illumination facilitate the sugar accumulation. We tried to establish a quantitative relation between the sugar content and these factors. As the index of illumination, we took a number of days with clear sky (taking into account low clouds) during the period of sugar accumulation beginning with the moment of root formation until harvesting. The coefficient of moistening reflects the moisture conditions throughout the vegetative period. We assumed that the formation of the assimilative apparatus, which is an important factor in sugar accumulation, depends on moisture conditions in the initial period of vegetation, while the process of sugar accumulation depends on moisture conditions in the period of this accumulation.

Table 1. Types of Climates and Their Characteristics with Respect to the Sugar Beet Cultivation

Climate	Sum of temperatures during vegetative period (degrees)	Coefficient of moistening	Root yield (centner/hectare)	Sugar production (centner/hectare)	Evaluation of sugar-beet yield and sugar production
Hot					
Dry	3400	< 1.0	≤ 200	≤ 25	Poor
Semiarid	3400	1.0 - 1.4	200 - 300	25 - 50	Below average
Moderately dry	3400	1.4 - 1.8	300 - 400	50 - 75	Average
Insufficiently moist	3400	1.8 - 2.2	400 - 500	75 - 100	Good
Moist	3400	2.2 - 3.5	≥ 500	≥ 100	Very good
Moderately Hot					
Dry	3400 - 3000	≤ 0.8	≤ 200	≤ 25	Poor
Semiarid	3400 - 3000	0.8 - 1.2	200 - 300	25 - 50	Below average
Moderately dry	3400 - 3000	1.2 - 1.6	300 - 400	50 - 75	Average
Insufficiently moist	3400 - 3000	1.6 - 2.0	400 - 500	75 - 100	Good
Moist	3400 - 3000	2.0 - 3.0	500	100	Very good
Excessively wet	3400 - 3000	> 3.0	400 - 500	75 - 100	Good
Warm					
Dry	3000 - 2400	≤ 0.8	≤ 200	≤ 25	Poor
Semiarid	3000 - 2400	0.8 - 1.2	200 - 300	25 - 50	Below average
Moderately dry	3000 - 2400	1.2 - 1.6	300 - 350	50 - 70	Average
Insufficiently moist	3000 - 2400	1.6 - 2.0	400 - 450	70 - 75	Good
Moist	3000 - 2400	2.0 - 3.0	400 - 450	70 - 75	"
Excessively wet	3000 - 2400	> 3.0	350 - 450	50 - 75	Average

(Continued)

Table 1 (Continuation)

Climate	Sum of temperatures during vegetative period (degrees)	Coefficient of moistening	Root yield (centner/hectare)	Sugar production (centner/hectare)	Evaluation of sugar-beet yield and sugar production
Moderately Warm					
Dry	2400 - 2000	≤0.6	< 200	≤ 25	Poor
Semiarid	2400 - 2000	0.6 - 1.0	≤200	≤25	"
Moderately dry	2400 - 2000	1.0 - 1.4	250	25	Below average
Insufficiently moist	2400 - 2000	1.4 - 1.8	300 - 350	> 50	Average
Moist	2400 - 2000	1.8 - 2.5	≥300 - 400	≥50 - 75	Good
Excessively wet	2400 - 2000	≥2.5	250 - 350	25 - 50	Average
Moderately Cool					
Dry	2000 - 1600	≤ 0.6	< 200	< 25	Poor
Semiarid	2000 - 1600	0.6 - 1.0	200	25	"
Moderately dry	2000 - 1600	1.0 - 1.4	200	25	Below average
Insufficiently moist	2000 - 1600	1.4 - 1.8	200 - 250	25	" "
Moist	2000 - 1600	1.8 - 2.8	200 - 300	25 - 50	" "
Excessively wet	2000 - 1600	> 2.8	≤200 - 250	≤ 25	Poor
Cool	≤1600°	≤ 0.6 >	< 200	< 25	"

To facilitate the usage of established relationships in agroclimatic zoning, Table 1 presents an interpretation of quantitative indexes by introducing a classification of climates with reference to sugar-beet growing. The listed types of climates were outlined on the basis of relationships established from materials secured in the steppe and forest territories of the USSR. It is natural that some types of climates, particularly hot and moderately hot climates, do not occur in Siberia.

Thermal resources of the territory were evaluated on the basis of the map presenting sums of active temperatures in the period from the date of the spring transition of the air temperature over 7° [2] to the date of the fall transition below 5°. For the construction of this map, average sums of temperatures, secured from many years of observation, were taken from graphs showing the annual march of air temperature. Data of 200 hydrometeorological stations of Western Siberia were used. Then, on the basis of regularities in fluctuations of the sums of temperatures in individual years established by F. F. Davitaya [1], the sum of temperatures with 80% expectancy was computed, i.e., it was expected that this sum of temperature will occur in 8 out of 10 years. The latter temperature was mapped. On the basis of this map showing thermal resources of the territory and on the basis of data on the heat requirements of the sugar beet (Table 1), zones of thermal conditions with reference to the sugar beet were outlined. The following thermal zones were distinguished within the territory of Western Siberia: cool (with the sum of temperatures less than 1600°), moderately cool (the sum of temperatures ranges from 1600 to 2000°), moderately warm (the sum of temperatures ranges from 2000 to 2400°) and warm (the sum of temperatures larger than 2400°).

The zoning of the sugar beet on the basis of thermal conditions gave an opportunity (1) to establish the northern boundary of commercial sugar-beet growing, and (2) to draw the conclusion that within the greatest part of the territory of Western Siberia, thermic conditions are rather favorable for obtaining good and fair sugar-beet yields.

We found that the sum of active temperatures lower than 1600°, under any moisture conditions, present a limit below which sugar-beet yields become poor and the cultivation of this crop becomes unprofitable. Hence, the 1600° isoline of the sum of temperatures passing through the localities Zlatoust, Karpinsk, Ivdel, Vasiss, Staritsa, Kargasok and Birilyussy presents (on the basis of thermal conditions) the northern boundary of commercial sugar-beet growing in Western Siberia. East of this territory, this boundary passes over Anzhero-Sudzhensk and Tayga, then skirts along the Kuznetsk depression and Salair ridge from all sides; in Mountainous Altai it passes somewhat to the south of Onguday. In the cool zone, the sugar beet can be cultivated everywhere as a forage crop especially in the south. In areas lying south of the 1600°- isoline, under conditions of sufficient moisture, it would be possible to obtain yearly on chernozem

soils yields ranging from 200 to 400 centners per hectare, if techniques of the same level as at strain-testing stations were used. As the technique improves, the sugar-beet yields would naturally increase. However, in areas with favorable climate, yields will be higher and lower expenditures of labor and funds will be involved.

There is no doubt that insufficient or excessive moisture lowers considerably the value of the thermic resources of a territory. We used the coefficient of moistening as the principal index of moisture conditions. It was computed on the basis of materials obtained from 255 meteorological stations. Then, taking into account the moisture requirements of the sugar beet and the coefficient of moistening, the following areas with different degrees of moisture were distinguished within the territory of Western Siberia: dry ($K \leq 0.6$), semiarid (K ranging from 0.6 to 1.0), moderately dry (K ranging from 1.0 to 1.4), insufficiently moist (K ranging from 1.4 to 1.8), and moist ($K > 1.8$). These areas were obtained on the basis of moistening coefficient of 80% expectancy, similarly as for the thermic conditions.

The zoning of a territory based on its moisture conditions, with reference to a certain crop, is of great importance from the viewpoint of differentiating the agricultural techniques for ensuring moisture for this crop. This zoning helps to separate areas where irrigation is necessary, as well as areas where yields can be considerably increased by additional moistening through snow retention and other methods. The amount of additional moisture needed for sugar-beet crops in certain agroclimatic areas can be tentatively computed from the formula of the coefficient of moistening.

A general evaluation of climatic conditions in Siberia favorable for sugar-beet growing can be done by means of the complex agroclimatic zoning with reference to this crop. This zoning includes the evaluation of heat and moisture conditions and takes into account other factors, such as the influence of frosts, a duration of illumination, and others.

Figure 2 shows the agroclimatic zoning of the sugar beet in Western Siberia. On the basis of heat and moisture conditions, 13 agroclimatic areas were distinguished here, each having a certain type of cli ate with reference to this crop.

Table 2 presents data on the expectancy during the vegetative period of certain thermic and moisture conditions determining values of sugar-beet yields in each agroclimatic zones. These data give an opportunity to use as a climatic boundary the moisture and thermic conditions most favorable for commercial sugar-beet growing.

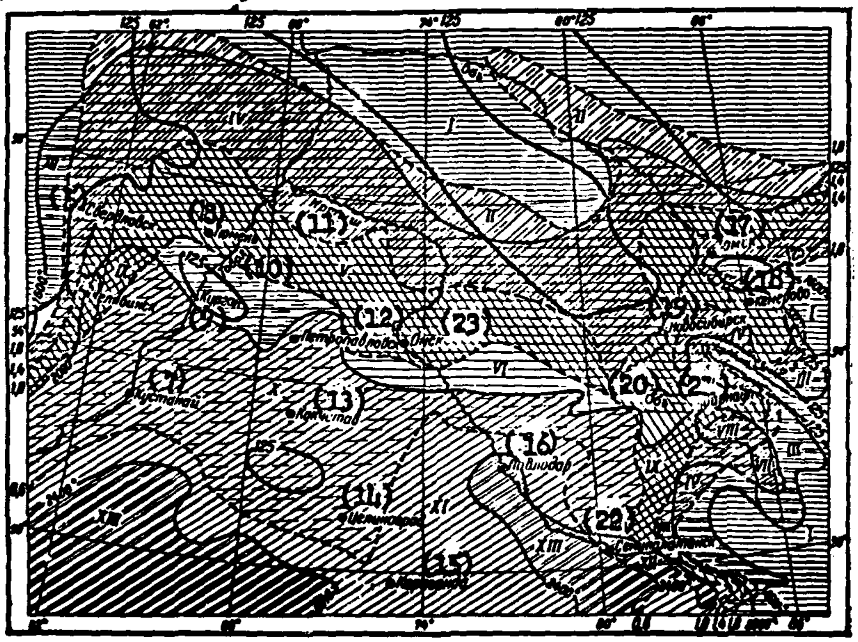


Figure 2. Agroclimatic zoning of the sugar beet in Western Siberia (geographic basis - a copy from the map of Western Siberia in Atlas mira (the World Atlas), on a scale 1 : 5,000,000).

KEY to Figure 2

1 - Isolines of sums of temperature ————

2 - Coefficient of moistening - - - - - -

3 - Boundary of the zone with 125 frost-free days

4 - Agroclimatic zones thermal and moisture conditions with 80% expectancy:

Cool, insufficiently moist

Moderately cool, moist

Cool, moist

Moderately cool, insufficient moistening

Moderately cool, moderately dry

Moderately cool, semiarid

Moderately warm, moist

Moderately warm, insufficient moistening

Moderately warm, moderately dry

Moderately warm, semiarid

Moderately warm, dry

Warm, semiarid

Warm, dry

5 - Sverdlovsk
6 - Chelyabinsk
7 - Kustanay
8 - Tyumen
9 - Kurgan
10 - Tobol
11 - Irtysh
12 - Petropavlovsk
13 - Kokchetav
14 - Tselinograd
15 - Karaganda
16 - Pavlodar
17 - Tomsk
18 - Kemerovo
19 - Novosibirsk
20 - Ob
21 - Barnaul
22 - Semipalatinsk
23 - Omsk

Table 2. Expectancy During the Vegetative Period of Different Complexes of Heat and Moisture Determining Certain Root Yields in Individual Agroclimatic Zones

Agroclimatic zones	Sum of temperatures and coefficient of moistening higher than:						
	1600°; 1.2	1800°; 1.4	2000°; 1.6	2200°; 1.8	2400°; 1.8	2800°; 1.8	3000°; 2.0
	Root yield (centner/hectare) higher than						
	200	250	300	350	400	450	500
	Expectancy (%)						
III*. Moderately cool and moist (Σt^o 1800°; K > 2.2**)	80 - 95	50 - 80	15 - 30	< 10	0		
IV. Moderately cool insufficiently moist (Σt^o 1800 - 2000°, K 2.2 - 1.8)	80 - 85	50 - 65	15 - 30	< 10	10	0	
V. Moderately cool moderately dry (Σt^o 2000 - 2200°, K 1.8 - 1.4)	85 - 65	65 - 50	25 - 30	< 10	0		
VI. Moderately cool semiarid(Σt^o 2200°, K 1.4)	65 - 35	40 - 20	20 - 10	< 10	0		
VII. Moderately warm and moist (Σt^o 2200 - 2400°, K > 2.2)	100	95	75 - 85	40 - 65	15 - 30	< 10	0

(Continued)

Table 2 (Continuation)

Agroclimatic zones	Sum of temperatures and coefficient of moistening higher than:						
	1600°; 1.2	1800°; 1.4	2000°; 1.6	2200°; 1.8	2400°; 1.8	2800°; 1.8	3000°; 2.0
	Root yield (centner/hectare) higher than						
	200	250	300	350	400	450	500
	Expectancy (%)						
VIII. Moderately warm insufficiently moist (Σt^o 2200 - 2400°, K 2.2 - 1.8)	100 - 85	95 - 75	75 - 60	40	15 - 25	<10	0
IX. Moderately warm moderately dry (Σt^o 2200 - 2400°, K 1.8 - 1.4)	85 - 65	75 - 50	50 - 35	25 - 15	<10	0	
X. Moderately warm semiarid (Σt^o 2200 - 2400°, K 1.4 - 1.0)	65 - 35	50 - 20	30 - 15	15 - <10	<10	0	
XI. Moderately warm dry (Σt^o 2400-2600°, K<1.0)	35	20	<10	0			
XII. Warm, semiarid (Σt^o 2600°, K 1.4 - 1.0)	65 - 35	50 - 20	35 - 15	20 - <10	15 - <10	<10	0
XIII. Warm and dry (Σt^o 2600° K<1.0)	35	20	10	<10	0		

* In the I and II agroclimati. zones, the average sum of temperatures less than 1800° (established from many years of observations) provides an yield lower than 200 centner/hectare under any conditions of moisture.

** Mean values of sums of temperatures and coefficients of moistening are presented (established on the basis of many years of observations).

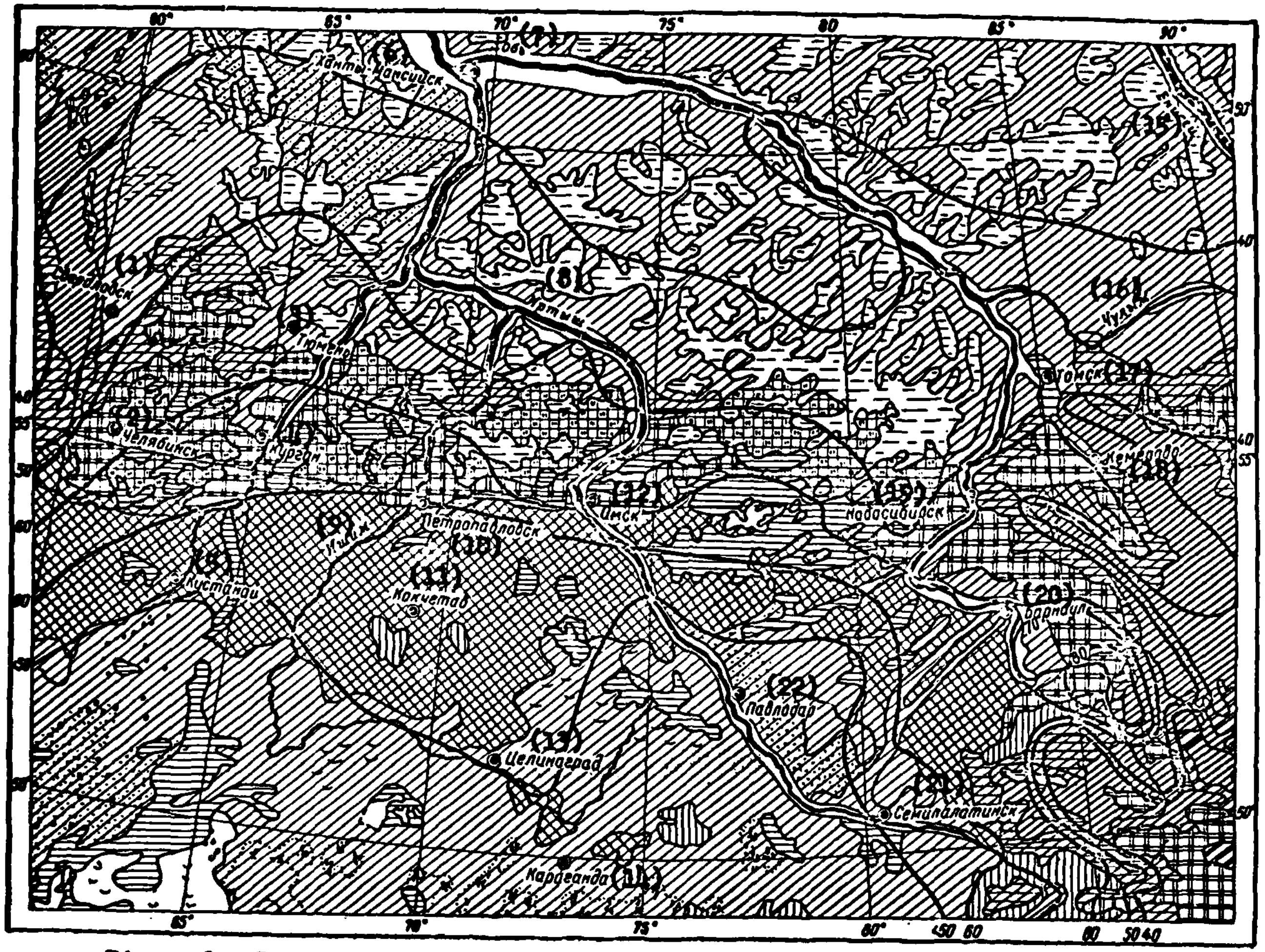


Figure 3. Schematic map showing the soil-climatic conditions of Western Siberia with reference to sugar-beet productivity.

KEY to Figure 3

Isolines showing equal values of climatic conditions

Soils on plains

- Podzolic and soddy-podzolic soils
- Grey forest soils under broad-leaved and small-leaved forests
- Leached and podzolized chernozems in the forest steppe
- Chernozems in the steppe zone
- Chestnut soils in dry steppes

- Brown soils of semideserts
- a b Peat-boggy soils: a) in compact masses
  b) in spots among other soils
- Meadow chernozemic soils
- Soddy-alluvial meadow soils
- a b Solonets (black alkali) soils: a) in large masses
  b) in spots among other soils
- Solods (degraded solonets)

Mountain soils

- Mountain-tundra soils
- Mountain-meadow soils
- Mountain-forest soils
- Mountain-forest podzolic soils
- Mountain-forest (chernozem, chestnut, and serozem) soils

Inscriptions on map:

1 - Sverdlovsk
2 - Chelyabinsk
3 - Tyumen
4 - Kurgan
5 - Kustanay
6 - Khanty-Mansiysk
7 - Ob
8 - Irtysh
9 - Ishim
10 - Petropavlovsk
11 - Kokchetav
12 - Omsk
13 - Tselingrad
14 - Karaganda
15 - Yenisey
16 - Chulym
17 - Tomsk
18 - Kemerovo
19 - Novosibirsk
20 - Barnaul
21 - Semipal[illegible]insk
22 - Pavlodar

A short frost-free period is the principal factor limiting the use of heat and moisture resources in Siberia. A reduction of the vegetative period is the most dangerous in northernmost areas of sugar-beet growing, where on a background of rather low sums of temperatures, the spring frosts occur late and the fall frosts arrive early. On the map showing the agroclimatic zones, a zone of northern and mountainous areas is distinguished where, due to frosts, sugar-beet yields are too low to substantiate commercial production. A minimum duration of the vegetative period equaling 125 days may serve as the boundary of this zone. North of this boundary, under conditions of a generally low thermal level, it is impossible to obtain sugar-beet yields high enough to be used commercially.

The influence of other climatic factors is not taken into account for the zoning, partly because this influence on the yield is insignificant (such as the interrelation between the day and night lengths), or because the values of these factors do not exceed the necessary limits (the minimum mean temperature of the warmest month). Also high temperatures should not be taken into account because in Siberia, under conditions of sufficient moisture, no temperatures high enough to be harmful for sugar-beet roots are observed.

Illumination in the period of sugar accumulation is an important factor for this accumulation and should be taken into account in the process of zoning. We established that the sugar content in roots exceeds 20% when there were from 40 to 100 clear days in the period of sugar accumulation, and when the coefficient of moistening ranged from 1.0 to 2.0. However, due to the fact that in Siberia the number of clear days is well correlated with the sum of temperatures used for the evaluation of the thermic resources of the territory, the factor of illumination is used indirectly which simplifies the map showing the agroclimatic zones.

From the standpoint of climatic conditions in Siberia, the most favorable zones for sugar-beet growing are: the moderately warm and moist (VII), moderately warm and insufficiently moist (VIII), and moderately warm and moderately dry (IX) zones. Here good yields are possible in most years and costs would be much lower than those in other areas.

Satisfactory moisture conditions permitting yields of 200 to 300 centners per hectare (on chernozem soils) are found in the moderately cool, moist (III) and moderately cool, insufficiently moist (IV) areas. Very high yields can be obtained in moderately warm and warm areas but a certain complex of cultivation methods should be elaborated to improve moisture conditions in soil.

A relative agricultural evaluation of the climatic conditions of the territory can be expressed also in relative values showing the changes in the sugar-beet productivity throughout the territory. The use of

relative indexes is based on the 100-point scale where the moder... ...t, moist climate is arbitrarily taken as corresponding to 100 points ... sum of temperatures from 3000° to 3400°, the coefficient of moistening K from 2.0 to 3.0).

Then according to our computations, climatic conditions within the agroclimatic zones of Western Siberia with reference to the sugar beet will be evaluated in terms of the above points as follows:

Zone I	<40	Zone V	55-60	Zone IX	70
Zone II	<40	Zone VI	60	Zone X	50-60
Zone III	40	Zone VII	75-80	Zone XI	<50
Zone IV	40-50	Zone VIII	70-75	Zone XII	55-70
				Zone XIII	<50.

In order to distinguish the areas most profitable for sugar-beet growing it is advisable to take into account not only climatic but also soil conditions. This can be achieved by plotting on a soil map data on the evaluation of the climatic conditions (Figure 3).

Proceeding from the soil requirements of the sugar beet and using a map showing a relative evaluation of soil-climatic conditions, it is easy to outline within the territory of Western Siberia areas where sugar-beet growing and sugar production would be profitable. For example, principal areas where sugar-beet growing is possible without considerable additional expenses for large-scale agricultural projects, such as irrigation and others, lie in the forest steppe in the zone of leached and podzolised chernosems and are bounded by the 60-80 point isoline describing the relative evaluation. The use of climatic resources of other areas would involve large expenses for projects to improve the water supply or the thermic conditions. Here the degree of the profitability of sugar beets would be determined wholly by economic conditions.

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